Estimation of tritium level for the KOPIO target

Thursday, February 13, 2003

From MCNPX, I calculated tritium fluxes in different surfaces around the tube containing the water and the platinum target. The flux is ~ 10^{-3} particles cm^{-2} per incident proton. Using the geometrical approximation, flux = density × interaction_length, where I take the interaction_length to be the length of the (inner) tube containing water and the platinum target, ie., 13.335 cm, I get density of tritium produced per incident proton (ρ) = 7.50×10^{-5} cm^{-3}.

Dilution by the water tank of 8.5 gallons V (1 gallon = 3.785 litres), ie., 32.1725 litres (1 litre = 1000 cm^{-3}). The water volume in the tube v is

$v = 4\pi/3\times R^3 + \pi R^2 L - \pi r^2 l$, where R is the radius of the inner tube and the sphere at the end of the tube, r the radius of the platinum, L the length of the inner tube and l the length of platinum,

$$= (\ 0.281 + 6.497 - 1.361\ )\ cm^3$$
$$= 5.417\ cm^3 \qquad (1)$$

$\therefore$ diluted tritium production density $\rho' = \rho \times v/(v+V)$

$$= 1.26 \times 10^{-8}\ cm^{-3} \text{ per incident proton}$$

$$\text{The no. of tritiums } (N_{\mathbf{tritium}}) \ = P \times (\ 1 - e^{-\lambda t}) / \lambda \qquad (2)$$

where P is production rate of tritium and λ is the decay constant. Here, since the half-life for the tritium is long (12.3 years),

$$N_{\mathbf{tritium}} \approx P \times (\ 1 - \ 1 + \lambda \times t\ ) / \lambda = P \times t$$

Now, we assume 100 TP (tera-proton) per 4.7 seconds and we run for 100 hours,

tritiums produced $= \rho' \times (\ 100 \times 10^{12}/ 4.7\ ) \times 100 \times 3600$

$$= 9.65 \times 10^{10}\ cm^{-3} \qquad (3)$$

Activity $= \lambda \times N_{\mathbf{tritium}}$

$$= \ln 2/\text{half\_life} \times 9.65 \times 10^{10}\ cm^{-3}$$
$$= 172.4\ Bq\ cm^{-3}$$
$$= 4.66\ \mu Ci\ /\ Litre \qquad (4)$$

Instantaneously, 100 TP (tera-protons) per 4.7 seconds would produce $\rho' \times 100 \times 10^{12}/ 4.7$ or 2.68×10^5 tritiums $cm^{-3}\ s^{-1}$. Sullivan[1] provides the activities for various isotopes for 10^{12} hadrons per second passing 1 cm of water. I scaled it (proportionally) with the above production rate that I have obtained for our specific geometry/volume/beam luminosity. The volume assumed is that of the tube containing water as in (1). The results are tabulated as follows:

Nuclide	O-14	O-15	N-13	C-11	Be-7	H-3
Half life	1.2 mins.	2.1 mins.	10 mins.	20 mins.	53 days	2.3 years
kBq/s per 1E12 hadrons/s	3.20E+02	7.30E+03	3.20E+02	9.00E+01	2.50E-02	1.80E-03
λ, s^{-1}	9.60E-03	5.50E-03	1.16E-03	5.78E-04	1.51E-07	1.79E-09
Equilibrium Activity (Bq) per 1E12 hadrons /s	3.33E+07	1.33E+09	2.76E+08	1.56E+08	1.66E+08	1.01E+09
Actual Activity (Bq) /cc	8.88E+03	3.54E+05	7.35E+04	4.15E+04	4.41E+04	2.68E+05
Actual Activity (Bq)	48123.02	1916171.3	398259.5	224796.1	239021.6	1451756
Dose (fSv/h/Bq at 1m)	450	140	140	140	8	
Dose in Rad/h (quality = 1) at 1 m	2.17E-06	2.68E-05	5.58E-06	3.15E-06	1.91E-07	
Dose in Rad/h (quality = 1) at 1 ft	2.33E-05	2.89E-04	6.00E-05	3.39E-05	2.06E-06	

According to Sullivan[1], the damage to rubber and organic cables would not start to become significant until the doses reach 1 million Rad and 10 million Rad respectively. So, the rubber here would be OK for billions of hours.

[1] A. H. Sullivan, "A Guide to Radiation and Radioactivity Levels near High Energy Particle Accelerators", Nuclear Technology Publishing, England, 1992.